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**Technical Report Series on the
Boreal Ecosystem-Atmosphere Study (BOREAS)**

Forrest G. Hall and Shelaine Curd, Editors

Volume 155

**BOREAS TE-9 NSA Leaf
Chlorophyll Density**

H. Margolis and M. Sy

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

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BOREAS TE-9 NSA Leaf Chlorophyll Density

Hank Margolis, Mikailou Sy

Summary

The BOREAS TE-9 team collected several data sets related to chemical and photosynthetic properties of leaves in boreal forest tree species. These data were collected to help provide an explanation of potential seasonal and spatial changes of leaf pigment properties in boreal forest species at the NSA. At different dates (FFC-Winter, FFC-Thaw, IFC-1, IFC-2, and IFC-3), foliage samples were collected from the upper third of the canopy for five NSA sites (YJP, OJP, OBS, UBS, and OA) near Thompson, Manitoba. Subsamples of 100 needles for black spruce, 20 needles for jack pine, and single leaf for trembling aspen were cut into pieces and immersed in a 20-mL DMF aliquot in a Nalgene test tube. The extracted foliage materials were then oven-dried at 68 °C for 48 hours and weighed. Extracted leaf dry weight was converted to a total leaf area basis to express the chlorophyll content in mg/cm² of total leaf area. The data are provided in tabular ASCII files.

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1. Data Set Overview

1.1 Data Set Identification

BOREAS TE-09 NSA Leaf Chlorophyll Density

1.2 Data Set Introduction

The BOREal Ecosystem-Atmosphere Study (BOREAS) Terrestrial Ecology (TE)-09 team provided several data sets containing information about the state and response of boreal forest tree species. This data set contains information on the spatial density of chlorophyll in the leaves of three boreal tree species collected at five different sites at various times during 1994.

1.3 Objective/Purpose

These data were collected to help provide an explanation of potential seasonal and spatial changes of leaf pigment properties in boreal forest species at the BOREAS Northern Study Area (NSA).

1.4 Summary of Parameters

Site ID, sample number, total chlorophyll density per total leaf area (mg/cm²).

1.5 Discussion

At different dates (Focused Field Campaign [FFC]-Winter, FFC-Thaw, Intensive Field Campaign [IFC]-1, IFC-2, and IFC-3), foliage samples were collected from the upper third of the canopy for five sites (Young Jack Pine [YJP], Old Jack Pine [OJP], Old Black Spruce [OBS], Upland Black Spruce [UBS], and Old Aspen [OA]) at the NSA in Thompson, Manitoba. For both winter and thaw periods, no sample was taken at the OA site. Samples were randomly harvested from five dominant trees (five replications), and analyses were conducted on three different subsamples per tree. Subsamples of 100 needles for black spruce, 20 needles for jack pine, and single leaf for trembling aspen were cut into pieces and immersed in a 20-mL N,N-Dimethylformamide (DMF) aliquot in a Nalgene test tube. In some cases, two extraction series were necessary to remove all the chlorophyll (Chl). These subsamples were wrapped in aluminum foil and stored at 4 °C in a cold chamber or a refrigerator throughout the extraction period. Aliquots were adjusted to 21 mL after extraction before absorbance measurements were taken at 647 and 664.5 nm using two optical glass cells in an ultraviolet/visible (UV/VIS) spectrophotometer. The extracted foliage materials were then oven-dried at 68 °C for 48 hours and weighed. Extracted leaf dry weight was converted to a total leaf area basis to express the Chl content in mg/cm² of total leaf area. Additional subsamples were collected from all samples (five replications) at all sampling dates and for all sites. Total leaf surface area (cm²) was measured using volume displacement method, leaf fresh weight (g), projected leaf area (cm²), and leaf dry weight (g). For aspen leaves, total leaf area was assumed to be double the projected leaf area. This method allowed calculation of the total leaf area/fresh weight ratio (cm²/g). Also, the leaf fresh weight (g) was measured, the Chl was extracted, and the residues were oven-dried to determine the leaf dry weight after extraction (g). This allowed calculation of the leaf dry weight after extraction/leaf fresh weight ratio. Multiplying (Chl / dry weight after extraction) x (dry weight after extraction / leaf fresh weight) x (leaf fresh weight / total leaf area) yielded the Chl concentration per total leaf area.

DMF is a very convenient solvent for Chl extraction because it is effective on intact plant parts and Chl is quite stable in DMF. Chl extracts were shown to be stable in DMF for up to 20 days when stored at 4 °C in the dark (Moran and Porath, 1980). Because Chl degrades at high temperatures, it is advisable to store tissues at a low temperature (not higher than 5 °C) until solvent extraction is completed. DMF extraction is often used because it avoids mechanical maceration and particle removal (Yoder and Deley, 1989). Furthermore, Moran and Porath (1980) found no differences in pigment concentration in DMF extracts prepared by grinding compared to those prepared by direct immersion. Inskeep and Bloom (1985) studied the absorption spectra of Chl a and Chl b in DMF and established equations that quantify Chl a, Chl b, and total Chl using absorbance measurements at 647 nm (maximum for Chl a) and at 664.5 nm (maximum for Chl b).

1.6 Related Data Sets

BOREAS TE-10 Leaf Chemistry Data

BOREAS RSS-04 1994 Jack Pine Leaf Biochemistry and Modeled Spectra in the SSA

2. Investigator(s)

2.1 Investigator(s) Name and Title

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Universite Laval
Faculte de foresterie et de geomatique
Pavillon Abitibi-Price

2.2 Title of Investigation

Relationship Between Measures of Absorbed and Reflected Radiation and the Photosynthetic Capacity of Boreal Forest Canopies and Understories

2.3 Contact Information

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3. Theory of Measurements

DMF is a very convenient solvent for Chl extraction because it is effective on intact plant parts and Chl is quite stable in DMF. Chl extracts were shown to be stable in DMF for up to 20 days when stored at 4 °C in the dark (Moran and Porath, 1980). Because Chl degrades at high temperatures, it is advisable to store tissues at a low temperature (not higher than 5 °C) until solvent extraction is completed. DMF extraction is often used because it avoids mechanical maceration and particle removal (Yoder and Deley, 1989). Furthermore, Moran and Porath (1980) found no differences in pigment concentration in DMF extracts prepared by grinding compared to those prepared by direct immersion. Inskeep and Bloom (1985) studied the absorption spectra of Chl a and Chl b in DMF and established equations that quantify Chl a, Chl b, and total Chl using absorbance measurements at 647 nm (maximum for Chl a)

and at 664.5 nm (maximum for Chl b).

Total leaf surface area (cm²) was measured using volume displacement method, leaf fresh weight (g), projected leaf area (cm²), and leaf dry weight (g). For aspen leaves, total leaf area was assumed to be double the projected leaf area. This method allowed calculation of the total leaf area/fresh weight ratio (cm²/g). Also, the leaf fresh weight (g) was measured, the Chl was extracted, and the residues were oven-dried to determine the leaf dry weight after extraction (g). This allowed calculation of the leaf dry weight after extraction/leaf fresh weight ratio. Multiplying (Chl / dry weight after extraction) x (dry weight after extraction / leaf fresh weight) x (leaf fresh weight / total leaf area) yielded the Chl concentration per total leaf area.

Total leaf area of conifer samples was obtained by the volume displacement method as described in Appendix C of the BOREAS Experiment Plan. The total length of needles and projected area of aspen leaves were obtained using an optical planimeter.

4. Equipment

4.1 Sensor/Instrument Description

Shotgun, cooler with ice, plastic bags, pruner, blade, DMF, automatic dispenser, optical glass cells, Nalgene calibrated tube, Nalgene test tubes, Eppendorf pipet, UV/VIS spectrophotometer, high-precision balance, optical planimeter.

4.1.1 Collection Environment

Two team members collected branches at all sites, kept them in identified plastic bags in a cooler, and transported them to the laboratory. Needles or leaves were then manually selected, immersed in DMF, wrapped in aluminum foil within a few hours of harvest, and kept at 4 °C. At the times of collection, ambient outdoor temperatures ranged from -10 to 25 °C.

4.1.2 Source/Platform

Ground collection with shotgun removal of foliage material.

4.1.3 Source/Platform Mission Objectives

The mission was undertaken in order to compare collected data with those from aircraft measurements. Also, these ground data were collected to help provide an explanation of potential seasonal and spatial changes of leaf pigment properties in boreal forest species at the NSA.

4.1.4 Key Variables

Chl density on a total leaf area basis.

4.1.5 Principles of Operation

For each subsample, foliage material was cut into four pieces and immersed in a 20-mL aliquot of DMF in a Nalgene test tube that was then wrapped in aluminum foil and kept in a dark chamber maintained at 4 °C. A shaker was used for faster Chl extraction. After 72 hours, the solvent was removed and adjusted to 21 mL using a 25-mL Nalgene calibrated tube. Another aliquot of 20 mL was added to the tube for a second extraction. Both adjusted aliquots were successively analyzed with the spectrophotometer, and the results were then combined. Extracted leaf materials were oven-dried and weighed. The dry weight was converted into total leaf area.

Total leaf area of conifer samples was obtained by the volume displacement method as described in Appendix C of the BOREAS Experiment Plan. The total length of needles and projected area of aspen leaves were obtained using an optical planimeter.

4.1.6 Sensor/Instrument Measurement Geometry

Samples were harvested from the upper third of the canopy of dominant trees at all sites and at all sampling periods.

4.1.7 Manufacturer of Sensor/Instrument

Projected leaf area or leaf length measurement system/optical image analysis system (AgVision, monochrome system, root and leaf analysis):

Decagon Devices, Inc.
P.O. Box 835
Pullman, WA 99163
(800) 755-2751

Spectrophotometer:
Perkin-Elmer, Lambda 3B, UV/VIS spectrophotometer
Oak Brook, IL

Dispenser:
Compet, 5-mL bottle top dispenser
Nichiryo Co. LTD.
Tokyo, Japan

Optical glass cells:
Hellma, 360-2500 nm, light path 10
Fisher Scientific,
8505 Devonshire Rd.
Montreal, Quebec
Canada H4P 2 L4

4.2 Calibration

4.2.1 Specifications

The weighing balance was accurate to within 0.0001 g. The leaf area system was accurate to within 1%. The automatic dispenser was accurate to within 1%. The spectrophotometer was accurate to within 0.001 absorbance unit.

4.2.1.1 Tolerance

The weighing balance was accurate to within 0.0001 g. The leaf area system was accurate to within 1%. The automatic dispenser was accurate to within 1%. The spectrophotometer was accurate to within 0.001 absorbance unit.

4.2.2 Frequency of Calibration

A control reading was taken on the spectrophotometer (0 absorbance unit) after each group of 15 samples using DMF as reference solvent in both optical glass cells. The leaf area system was calibrated once for each sampling date. The weighing balance was tared after each group of 15 samples. All foliage materials were oven-dried at 68 °C for 48 hours.

4.2.3 Other Calibration Information

Not available.

5. Data Acquisition Methods

Sites: Samples were collected from five sites at the NSA in Thompson, Manitoba. The sites are described in Appendix I and can be identified in Figure 5.1.5a of the BOREAS Experiment Plan Version 3.0.

NSA-YJP: T8S9T
NSA-OJP: T7Q8T
NSA-OBS: T3R8T
NSA-BS: T6R5S
NSA-OA: T2Q6A

Sampling: Sampling dates, except those in the winter and thaw periods, generally correspond to either the day of or the day following the Airborne Visible and Infrared Imaging Spectrometer (AVIRIS) missions. For each site, branches were cut from the upper third of the canopy of five dominant trees in a representative location using a shotgun. Branches were kept in identified plastic bags, stored in a cooler with ice, and transported to the laboratory in Thompson. From each bag, three subsamples of 100 needles each for black spruce, 20 needles for jack pine, and a single leaf for trembling aspen were collected and immersed in a 20-mL aliquot of DMF solvent for extraction. Two additional equivalent subsamples were taken from each bag, for obtaining information on (dry weight after extraction / leaf fresh weight) and (leaf fresh weight / total leaf area).

Extraction: An automatic dispenser was used to deliver the 20-mL aliquots in Nalgene tubes, which were wrapped with aluminum foil to avoid light degradation effects on Chl and stored at 4 °C in a refrigerator. Samples were then transported to Laval University in Quebec City. Needles and aspen leaves were cut into pieces, and tubes were maintained on a shaker for faster Chl extraction. These first extracts were adjusted to 21 mL after 1 week, and the absorbance measurements were taken using two optical glass cells and a UV/VIS spectrophotometer. A second extraction was run following the same procedure.

Absorbance measurements: For each subsample, absorbance measurements were taken successively at 647 and 664.5 nm using a 2-mL aliquot of the extracts in an optical glass cell. The other cell contained a 2-mL aliquot of DMF as the reference solvent. Spectrophotometer zeroing was done after each group of 15 subsamples.

6. Observations

6.1 Data Notes

None.

6.2 Field Notes

None given.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

Samples were collected in a 20-m-diameter area from five dominant trees. Sampling location was chosen to be like the tower flux or the canopy access tower location. Sampling location changed from date to date. The North American Datum of 1983 (NAD83) coordinates for the sites are:

- NSA-YJP = Lat/Long: 55.895°N, 98.28706°W; Universal Transverse Mercator (UTM) Zone 14 N:6194706 E:544583
- NSA-OJP = Lat/Long: 55.928°N, 98.624°W; UTM Zone 14 N:6198176 E:523496
- NSA-OBS = Lat/Long: 55.880°N, 98.481°W; UTM Zone 14 N:6192853 E:532444
- NSA-UBS = Lat/Long: 55.908°N, 98.519°W; UTM Zone 14 N:6195947 E:530092
- NSA-OA = Lat/Long: 55.887°N, 98.675°W; UTM Zone 14 N:6193540 E:520342

7.1.2 Spatial Coverage Map

Not available.

7.1.3 Spatial Resolution

These data represent measurements taken from longitude coordinates. The user will need to assume how representative they are for extrapolation.

7.1.4 Projection

Not applicable.

7.1.5 Grid Description

Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage

The overall period of sample acquisition was from 01-Feb-1994 through 18-Sep-1994. Extractions were run immediately after harvesting, and analyses were conducted within 1 week of each sampling date. The precise dates of sampling were as follows:

IFC	Sites (NSA) and Dates
FFC-W	OJP, OBS, and YJP on 17-Feb-1994 TE-BS on 18-Feb-1994
FFC-T	OJP, OBS, and YJP on 28-Apr-1994 TE-BS on 29-Apr-1994
IFC-1	OA, OJP, and YJP on 08-Jun-1994 OBS and BS on 09-Jun-1994
IFC-2	OASP, OJP, and BS on 04-Aug-1994 OBS and YJP on 05-Aug-1994
IFC-3	OBS on 15-Sep-1994 OASP, YJP, OJP, and BS on 16-Sep-1994

7.2.2 Temporal Coverage Map

The precise dates of sampling are shown above.

7.2.3 Temporal Resolution

For each sampling date, branches were collected at 6:00 a.m. in OBS; at 8:00 a.m. in YJP; and between 3:00 and 6:00 p.m. in UBS, OJP, and OA. After Chl extraction, spectrophotometer measurements were taken on the same day.

7.3 Data Characteristics

7.3.1 Parameter/Variable

The parameters contained in the data files on the CD-ROM are:

Column Name
SITE_NAME
SUB_SITE
DATE_COLLECTED
TIME_COLLECTED
SAMPLE_ID
SPECIES
CHLOROPHYLL_DENSITY
CRTFCN_CODE
REVISION_DATE

7.3.2 Variable Description/Definition

The descriptions of the parameters contained in the data files on the CD-ROM are:

Column Name	Description
SITE_NAME	The identifier assigned to the site by BOREAS, in the format SSS-TTT-CCCCC, where SSS identifies the portion of the study area: NSA, SSA, REG, T RN, and TTT identifies the cover type for the site, 999 if unknown, and CCCCC is the identifier for site, exactly what it means will vary with site type.
SUB_SITE	The identifier assigned to the sub-site by BOREAS, in the format GGGGG-III III, where GGGGG is the group associated with the sub-site instrument, e.g. HYD06 or STAFF, and III III is the identifier for sub-site, often this will refer to an instrument.
DATE_COLLECTED	The date on which the samples were collected.
TIME_COLLECTED	The Greenwich Mean Time (GMT) when the samples were collected.
SAMPLE_ID	The sample identifier used by data collectors (see documentation for a detailed description).
SPECIES	Botanical (Latin) name of the species (Genus species).
CHLOROPHYLL_DENSITY	Chlorophyll density per unit area of a given sample.
CRTFCN_CODE	The BOREAS certification level of the data. Examples are CPI (Checked by PI), CGR (Certified by Group), PRE (Preliminary), and CPI-??? (CPI but questionable).
REVISION_DATE	The most recent date when the information in the referenced data base table record was revised.

7.3.3 Unit of Measurement

The measurement units for the parameters contained in the data files on the CD-ROM are:

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
DATE_COLLECTED	[DD-MON-YY]
TIME_COLLECTED	[HHMM GMT]
SAMPLE_ID	[none]
SPECIES	[none]
CHLOROPHYLL_DENSITY	[milligrams] [meter ⁻²]
CRTFCN_CODE	[none]
REVISION_DATE	[DD-MON-YY]

7.3.4 Data Source

The sources of the parameter values contained in the data files on the CD-ROM are:

Column Name	Data Source
SITE_NAME	[BORIS Designation]
SUB_SITE	[BORIS Designation]
DATE_COLLECTED	[Human Observer]
TIME_COLLECTED	[Human Observer]
SAMPLE_ID	[Human Observer]
SPECIES	[Human Observer]
CHLOROPHYLL_DENSITY	[Laboratory Equipment]
CRTFCN_CODE	[BORIS Designation]
REVISION_DATE	[BORIS Designation]

7.3.5 Data Range

The following table gives information about the parameter values found in the data files on the CD-ROM.

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SITE_NAME	NSA-9BS-9TETR	NSA-YJP-FLXTR	None	None	None	None
SUB_SITE	9TE09-CHL01	9TE09-CHL01	None	None	None	None
DATE_COLLECTED	17-FEB-94	16-SEP-94	None	None	None	None
TIME_COLLECTED	1100	2100	None	None	None	None
SAMPLE_ID	1.1	5.3	None	None	None	None
SPECIES	N/A	N/A	None	None	None	None
CHLOROPHYLL_DENSITY	9.9	266.8	-999	None	None	None
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	18-SEP-96	18-SEP-96	None	None	None	None

Minimum Data Value -- The minimum value found in the column.

Maximum Data Value -- The maximum value found in the column.

Missng Data Value -- The value that indicates missing data. This is used to indicate that an attempt was made to determine the parameter value, but the attempt was unsuccessful.

Unrel Data Value -- The value that indicates unreliable data. This is used to indicate an attempt was made to determine the

parameter value, but the value was deemed to be unreliable by the analysis personnel.

Below Detect Limit -- The value that indicates parameter values below the instruments detection limits. This is used to indicate that an attempt was made to determine the parameter value, but the analysis personnel determined that the parameter value was below the detection limit of the instrumentation.

Data Not Cllctd -- This value indicates that no attempt was made to determine the parameter value. This usually indicates that BORIS combined several similar but not identical data sets into the same data base table but this particular science team did not measure that parameter.

Blank -- Indicates that blank spaces are used to denote that type of value.

N/A -- Indicates that the value is not applicable to the respective column.

None -- Indicates that no values of that sort were found in the column.

7.4 Sample Data Record

The following is a sample of the first few records from the data table on the CD-ROM:

```
SITE_NAME,SUB_SITE,DATE_COLLECTED,TIME_COLLECTED,SAMPLE_ID,SPECIES,
CHLOROPHYLL_DENSITY,CRTFCN_CODE,REVISION_DATE
'NSA-9BS-9TETR','9TE09-CHL01',18-FEB-94,2100,'1.1','Picea mariana',149.6,'CPI',
18-SEP-96
'NSA-9BS-9TETR','9TE09-CHL01',29-APR-94,2000,'1.1','Picea mariana',87.1,'CPI',
18-SEP-96
```

8. Data Organization

8.1 Data Granularity

The smallest unit of data tracked by BOREAS Information System (BORIS) staff was that collected at a given site on a given date.

8.2 Data Format(s)

The Compact Disk-Read-Only Memory (CD-ROM) files contain American Standard Code for Information Interchange (ASCII) numerical and character fields of varying length separated by commas. The character fields are enclosed with single apostrophe marks. There are no spaces between the fields.

Each data file on the CD-ROM has four header lines of Hyper-Text Markup Language (HTML) code at the top. When viewed with a Web browser, this code displays header information (data set title, location, date, acknowledgments, etc.) and a series of HTML links to associated data files and related data sets. Line 5 of each data file is a list of the column names, and line 6 and following lines contain the actual data.

9. Data Manipulations

9.1 Formulae

9.1.1 Derivation Techniques and Algorithms

Chl density was calculated using the following equations:

$$T1 = 17.9 \cdot D_{647} + 8.08 \cdot D_{664.5} \text{ (mg/L)}$$

where: D is the absorbance at the indicated wavelength.

$$TCHL_x = (T1 \cdot 0.021 \cdot B_x) / (A_x \cdot LDW_x) \text{ (mg/cm}^2\text{)}$$

where: 0.021 is the aliquot volume (L)

A_x is the total leaf area/fresh weight ratio (cm²/g)

B_x is the dry weight after extraction/fresh weight ratio

LDW_x is leaf dry weight after extraction (g).

9.2 Data Processing Sequence

9.2.1 Processing Steps

Not applicable.

9.2.2 Processing Changes

Not applicable.

9.3 Calculations

9.3.1 Special Corrections/Adjustments

Extractions were made to remove all leaf Chl content. Volume adjustments were made uniformly. Spectrophotometer readings were carefully conducted.

The weighing balance used for volume displacement was accurate to 0.0001 g. Projected leaf area for aspen and total length of needles were measured using a well-calibrated system image analysis system ($\pm 1\%$ error).

9.3.2 Calculated Variables

Chl density was calculated using the following equations:

$$T1 = 17.9 \cdot D_{647} + 8.08 \cdot D_{664.5} \text{ (mg/L)}$$

where: D is the absorbance at the indicated wavelength.

$$TCHL_x = (T1 \cdot 0.021 \cdot B_x) / (A_x \cdot LDW_x) \text{ (mg/cm}^2\text{)}$$

where: 0.021 is the aliquot volume (L)

A_x is the total leaf area/fresh weight ratio (cm²/g)

B_x is the dry weight after extraction/fresh weight ratio

LDW_x is leaf dry weight after extraction (g).

9.4 Graphs and Plots

None.

10. Errors

10.1 Sources of Error

Extractions were made to remove all leaf Chl content. Volume adjustments were made uniformly. Spectrophotometer readings were carefully conducted.

The weighing balance used for volume displacement was accurate to 0.0001 g. Projected leaf area for aspen and total length of needles were measured using a well-calibrated image analysis system ($\pm 1\%$ error).

10.2 Quality Assessment

None given.

10.2.1 Data Validation by Source

Data were checked for obvious readings and results.

10.2.2 Confidence Level/Accuracy Judgment

High.

10.2.3 Measurement Error for Parameters

Not applicable.

10.2.4 Additional Quality Assessments

Not applicable.

10.2.5 Data Verification by Data Center

BORIS staff reviewed the data for scientific clarity, consistency, and agreement with provided documentation.

11. Notes

11.1 Limitations of the Data

Only single extractions were done for the winter and thaw sampling dates. All the Chl was extracted. Two extractions were necessary for IFCs 1, 2, and 3.

11.2 Known Problems with the Data

None.

11.3 Usage Guidance

Only single extractions were done for the winter and thaw sampling dates. All the Chl was extracted. Two extractions were necessary for IFCs 1, 2, and 3.

11.4 Other Relevant Information

Not applicable.

12. Application of the Data Set

These data can be used for studies considering leaf Chl content as well as for photosynthesis rate studies.

13. Future Modifications and Plans

Not applicable.

14. Software

14.1 Software Description

None given.

14.2 Software Access

None given.

15. Data Access

The TE-09 leaf chlorophyll density data are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

15.1 Contact Information

For BOREAS data and documentation please contact:

ORNL DAAC User Services
Oak Ridge National Laboratory
P.O. Box 2008 MS-6407
Oak Ridge, TN 37831-6407
Phone: (423) 241-3952
Fax: (423) 574-4665
E-mail: ornldaac@ornl.gov or ornl@eos.nasa.gov

15.2 Data Center Identification

Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics
<http://www-eosdis.ornl.gov/>.

15.3 Procedures for Obtaining Data

Users may obtain data directly through the ORNL DAAC online search and order system [<http://www-eosdis.ornl.gov/>] and the anonymous FTP site [<ftp://www-eosdis.ornl.gov/data/>] or by contacting User Services by electronic mail, telephone, fax, letter, or personal visit using the contact information in Section 15.1.

15.4 Data Center Status/Plans

The ORNL DAAC is the primary source for BOREAS field measurement, image, GIS, and hardcopy data products. The BOREAS CD-ROM and data referenced or listed in inventories on the CD-ROM are available from the ORNL DAAC.

16. Output Products and Availability

16.1 Tape Products

None.

16.2 Film Products

None.

16.3 Other Products

These data are available on the BOREAS CD-ROM series.

17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation

None.

17.2 Journal Articles and Study Reports

Inskeep, W.P. and P.R. Bloom. 1985. Extinction coefficients of Chlorophyll a and b in N,N-Dimethylformamide and 80% Acetone. *Plant Physiol.* 77: 483-485.

Moran, R. and D. Porath. 1980. Chlorophyll determination in intact tissues using N,N-Dimethylformamide. *Plant Physiol.* 65: 478-479.

Newcomer, J., D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers, eds. 2000. *Collected Data of The Boreal Ecosystem-Atmosphere Study*. NASA. CD-ROM.

Sellers, P. and F. Hall. 1994. *Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1994-3.0*, NASA BOREAS Report (EXPLAN 94).

Sellers, P. and F. Hall. 1996. *Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1996-2.0*, NASA BOREAS Report (EXPLAN 96).

Sellers, P., F. Hall, and K.F. Huemmrich. 1996. *Boreal Ecosystem-Atmosphere Study: 1994 Operations*. NASA BOREAS Report (OPS DOC 94).

Sellers, P., F. Hall, and K.F. Huemmrich. 1997. *Boreal Ecosystem-Atmosphere Study: 1996 Operations*. NASA BOREAS Report (OPS DOC 96).

Sellers, P., F. Hall, H. Margolis, B. Kelly, D. Baldocchi, G. den Hartog, J. Cihlar, M.G. Ryan, B. Goodison, P. Crill, K.J. Ranson, D. Lettenmaier, and D.E. Wickland. 1995. The boreal ecosystem-atmosphere study (BOREAS): an overview and early results from the 1994 field year. *Bulletin of the American Meteorological Society.* 76(9):1549-1577.

Sellers, P.J., F.G. Hall, R.D. Kelly, A. Black, D. Baldocchi, J. Berry, M. Ryan, K.J. Ranson, P.M. Crill, D.P. Lettenmaier, H. Margolis, J. Cihlar, J. Newcomer, D. Fitzjarrald, P.G. Jarvis, S.T. Gower, D. Halliwell, D. Williams, B. Goodison, D.E. Wickland, and F.E. Guertin. 1997. BOREAS in 1997: Experiment Overview, Scientific Results and Future Directions. *Journal of Geophysical Research* 102(D24): 28,731-28,770.

Yoder, B.J. and L.S. Daley. 1989. Development of a visible spectroscopic method for determining chlorophyll a and b in vivo in leaf samples. *Spectroscopy* 8: 44-50.

17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

None.

19. List of Acronyms

ASCII	- American Standard Code for Information Interchange
AVIRIS	- Airborne Visible and Infrared Imaging Spectrometer
BOREAS	- BOREal Ecosystem-Atmosphere Study
BORIS	- BOREAS Information System
CD-ROM	- Compact Disk-Read-Only Memory
Chl	- Chlorophyll
DAAC	- Distributed Active Archive Center
DMF	- N,N-Dimethylformamide
EOS	- Earth Observing System
EOSDIS	- EOS Data and Information System
FFC	- Focused Field Campaign
GIS	- Geographic Information System
GMT	- Greenwich Mean Time
GSFC	- Goddard Space Flight Center
HTML	- HyperText Markup Language
IFC	- Intensive Field Campaign
NAD83	- North American Datum of 1983
NASA	- National Aeronautics and Space Administration
NSA	- Northern Study Area
OA	- Old Aspen
OBS	- Old Black Spruce
OJP	- Old Jack Pine
ORNL	- Oak Ridge National Laboratory
PANP	- Prince Albert National Park
SSA	- Southern Study Area
TE	- Terrestrial Ecology
UBS	- Upland Black Spruce site
URL	- Uniform Resource Locator
UTM	- Universal Transverse Mercator
UV-VIS	- Ultraviolet/Visible
YJP	- Young Jack Pine

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Samples were collected by Hank Margolis and other TE-09 members at five sites in the NSA (Thompson, Manitoba) for different dates (FFC-Winter, FFC-Thaw, IFC-1, IFC-2, and IFC-3). Sites were OBS, UBS, YJP, OJP, and OA. Laboratory analyses were conducted by Mikailou Sy.

If using data from the BOREAS CD-ROM series, also reference the data as:

Margolis, H., "Relationship Between Measures of Absorbed and Reflected Radiation and the Photosynthetic Capacity of Boreal Forest Canopies and Understories." In *Collected Data of The Boreal Ecosystem-Atmosphere Study*. Eds. J. Newcomer, D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers. CD-ROM. NASA, 2000.

Also, cite the BOREAS CD-ROM set as:

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20.5 Document Curator

20.6 Document URL

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13. ABSTRACT (Maximum 200 words) The BOREAS TE-9 team collected several data sets related to chemical and photosynthetic properties of leaves in boreal forest tree species. These data were collected to help provide an explanation of potential seasonal and spatial changes of leaf pigment properties in boreal forest species at the NSA. At different dates (FFC-Winter, FFC-Thaw, IFC-1, IFC-2, and IFC-3), foliage samples were collected from the upper third of the canopy for five NSA sites (YJP, OJP, OBS, UBS, and OA) near Thompson, Manitoba. Subsamples of 100 needles for black spruce, 20 needles for jack pine, and single leaf for trembling aspen were cut into pieces and immersed in a 20-mL DMF aliquot in a Nalgene test tube. The extracted foliage materials were then oven-dried at 68 °C for 48 hours and weighed. Extracted leaf dry weight was converted to a total leaf area basis to express the chlorophyll content in mg/cm ² of total leaf area. The data are provided in tabular ASCII files.				
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